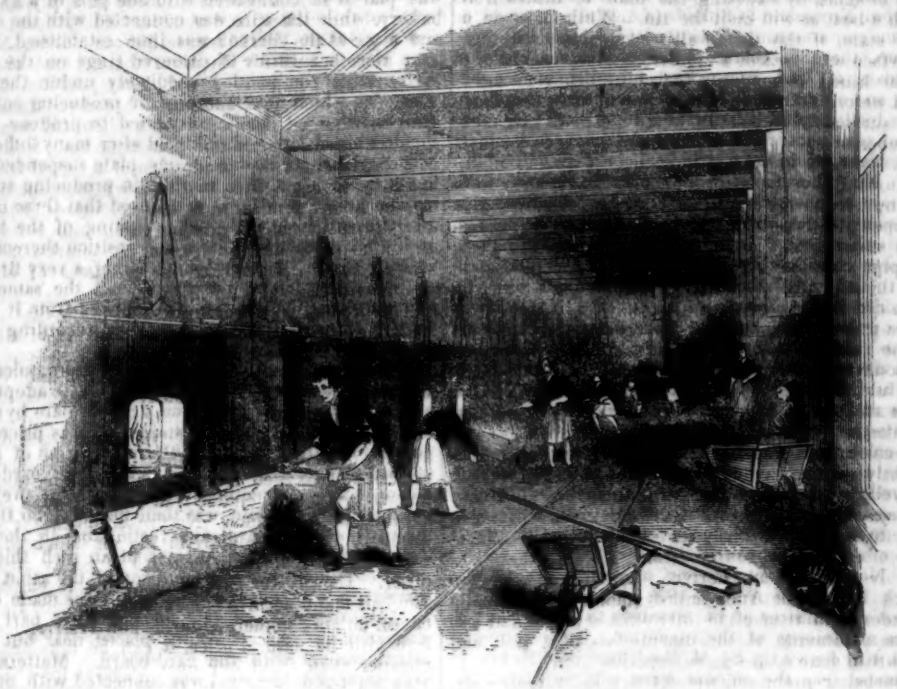
A DAY AT THE FELLING CHEMICAL-WORKS, NEWCASTLE.



[Soda-Furnaces, Felling Chemical-Works.]

THE factory which will form the subject of our present "visit" is one of a highly interesting class; a class influenced both by political and by scientific events in a remarkable degree: we allude to *Chemical Works*—those large establishments wherein are manufactured the chief acids, alkalis, and salts employed in science or in the arts.

That such establishments should be affected by the current of scientific discovery is what may reasonably be expected, since every advance in our knowledge of the constitution of bodies is likely to work changes in the modes of producing those substances. But in what way political matters are found to bear on the question may not be so obvious. A few considerations will, however, tend to show the kind of connection between these apparently disconnected agencies. If a manufacturer prepares certain chemical substances, (say) from sulphur; and if political, or diplomatic, or fiscal disagreements should occur between England and the country whence this sulphur is produced, then the manufacturer might be constrained to procure his sulphur from some other source, perhaps by a complicated process on one of the English ores of sulphur. Again, suppose the English government removes the tax previously imposed at a heavy rate on some article of abundant supply, such as common salt, then the manufacturer may be induced to employ this material as a fund whence he may procure acids or alkalis previously procured from a more expensive source. Now these are not merely supposed cases; they have actually occurred within the last few years, as we shall show farther on; and they illustrate the kind of effect which legislative or political occurrences are calculated to produce on chemical manufactures. The imposition or the removal of an excise duty on a commodity of home production; the imposition or the removal of a customs' duty on an imported foreign product; the establishment or the cessation of commercial intercourse with a country richly provided with some commodity which we require in our manufactures; the concentration, in the hands of a few, of a commodity required by the many; the legislative enactments which occasionally give rise to a demand for a particular commodity at a particular time;—all or any of these may work great changes in the arrangements of an establishment where chemical manufactures are carried on, irrespective of the still greater changes which naturally result from scientific discoveries in chemistry.

Chemical manufactures, like most others on a large scale, are carried on chiefly in the midland and northern counties. In most instances the chemical works are situated somewhat beyond the precincts of a large manufacturing town, since they require more space than can conveniently be procured within a town, and are liable to give off vapours and gaseous products, which are better at a distance than in close proximity to dwelling-houses. They are also generally situated near seaports, for convenience of shipment. Glasgow, Newcastle-upon-Tyne, and Liverpool are perhaps the three principal centres for this class of manufactures; and it is to one of these three that our present details will relate. By the kindness of Messrs. John Lee & Co., of the Felling Chemical-Works, near Newcastle, we hope to be enabled to convey a general idea of the nature and arrangements of such establishments as these. In no one establishment can we see more than a few chemical substances under process of manufac-

ture; for this, like all other departments of industry, is subdivided into distinct branches: but a few of the leading substances may be taken as types of the whole.

The busy Tyne exhibits along both its banks, all the way from Newcastle to Shields (a distance of seven or eight miles), a continued succession of factories—here of glass, there of coarse pottery; at other spots of chemicals, of lead, iron-works, oil-mills, engine-factories, and others which tend to swell the importance of this bustling and thriving neighbourhood. Of these seats of manufacture, the chemical works are the most conspicuous, from the enormous height of their chimneys. No other factories or works have such lofty chimneys as chemical works, because no others give forth so many gaseous products likely to be of a deleterious character. In some of these instances the chimneys considerably exceed St. Paul's cathedral in height; and indeed there is in Scotland one which is a hundred feet higher than St. Paul's! In past times many of the chemical works were regarded (and correctly so) as pests and plague-spots, bringing desolation on all the vegetable products near them; blasting the trees, and stunting the growth of almost every kind of field and garden produce. Numerous were the disputes between the various parties on these points; and an avowed good was, in this respect, always accompanied by an equally avowed evil. But modern research has wrought surprising changes in this respect. Every year adds something to the list of processes whereby a deleterious gas, previously sent forth into the atmosphere, becomes a source from which other and valuable products are derived: and it is scarcely too much to expect that such improvements will gradually be made as to render the lofty chimneys less and less necessary—leaving them as memorials of a past and less skilful state of the manufacturing arts.

This being premised, we will proceed on our visit. The Tyne separates Newcastle from Gateshead, the latter being to the former what Southwark is to London; and at a distance of a mile or two eastward from Gateshead is the village of Felling, where the chemical works are situated. The works occupy a position between the South Shields Railway and the river; and like most places in the neighbourhood, have abundant means of intercourse with the great central depôt, Newcastle, by cheap railways and still cheaper steamboats. The Londoners have their fourpenny steamers, but the good folks of Newcastle can have a nine miles' trip for threepence; and this facility, together with railways running along both banks of the Tyne, gives rise to an incessant and extensive intercourse.

On approaching the works, it is soon evident that they are of the class where a large number of buildings are spread over a great area of ground, rather than exhibiting one huge building, such as is so often seen in the cotton districts. The buildings are of various sizes and shapes: some lofty, some shallow; some long and broad, others nearly square; some exhibiting within dry and dusty processes, others heat and vapour, others vessels and liquids; one with a lofty and well-proportioned chimney, others with chimneys of more humble dimensions. Narrow passages and square courts separate these buildings one from another; and while passing through these passages, and the buildings adjacent to them, we become sensibly alive to the odour of the acids and other chemicals under process of manufacture.

The internal arrangements, and the nature of the operations carried on, will be best described by taking the chief objects of manufacture, and tracing them through their successive stages of progress.

Common *sulphur* and common *salt* are the two great agents in the production of the chemicals in most familiar use. Sulphuric acid, or 'oil of vitriol,' chloride of lime, or 'bleaching-powder,' muriatic acid, or 'spirit of salt,' the soda-ash employed by glass-makers and soap-makers, the common soda employed in washing—all result from certain modes of applying one or other of these cheap and abundant substances; and all are made at the Works now under our notice. Nothing can more beautifully illustrate the general character of chemical composition and decomposition than the steps by which one substance becomes transformed into another, as developed at a chemical work: the production of an acrid and poisonous body from harmless ingredients; the production of a liquid from two gases, or of a gas from two liquids; the generation of colour from the mixture of two colourless bodies; the transformation of an opaque earth into a colourless crystal;—these and analogous phenomena are constantly presented during the progress of chemical manufactures.

The production of sulphuric acid is the first point to which we will direct attention, and is, of all those carried on at the great chemical works, one of the most interesting to a stranger, who can hardly fail to be struck with the enormously large apparatus employed in some parts of the process.

Sulphuric acid is composed of sulphur and oxygen; and the principle of the manufacture rests on the abstraction of oxygen from the atmosphere, under circumstances which enable it to combine with common sulphur or brimstone. Nature supplies the one ingredient most abundantly in the air which surrounds us; while the volcanic districts of Sicily supply the other. The greater part of the sulphur employed in English manufactures comes from Sicily or Italy; because, unless commercial tariffs and restrictions interfere with its natural price, it can be obtained thence cheaper than from our own mineral districts. The English sulphur is only found in combination with other substances, such as in ores of copper and of iron, and requires a careful process for its separation. Hence, at the Felling Works (and these illustrate the general system of arrangements), when commerce is allowed to follow its own track between Italy and England, the Italian sulphur is used; whereas, in case circumstances should drive up the price of that commodity beyond a certain limit, apparatus is provided for the extraction of sulphur from iron pyrites, a mineral extensively found in this country.

About six years ago the price of Sicilian sulphur was driven up rapidly, through the following circumstances. (We quote from the 'Penny Cyclopædia.') "The *Sicilian* sulphur-mines are the property of individuals; and from fifteen to twenty English firms, settled in Sicily, are engaged in the trade. In 1836 M. Taix, a Frenchman, laid before the Sicilian government a project for establishing a company, which was to have the exclusive right, during ten years, of purchasing Sicilian sulphur at fixed prices, on condition of spending 10,000*l.* a year in constructing roads, and exporting one-third of the quantity produced in Sicilian vessels. The British merchants becoming alarmed, the Sicilian government, in reply to the British ambassador, stated that no such project would be adopted; it would have been in direct contravention to certain commercial treaties between the two governments. The Sicilian government did, however, enter into a contract with M. Taix, and on the 4th of July, 1838, notice was given at Palermo, that the monopoly would come into operation on the 1st of August ensuing. The negotiations respecting this monopoly were conducted with great secrecy; and it came into operation so suddenly that twenty-four vessels lost their cargoes. The British lessees of mines, and all others, were compelled to produce only a fixed

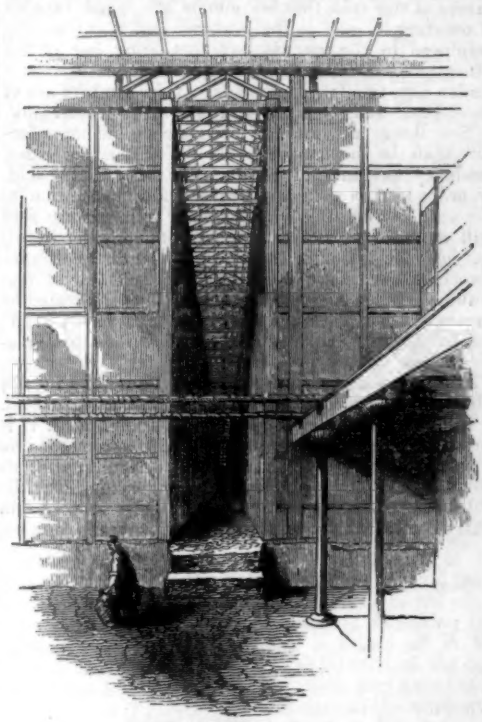
quantity of sulphur; prices rose from 6*l.* 10*s.* or 7*l.* to 13*l.* and 14*l.* per ton, and contracts could not be completed. Previous to the monopoly, 484 British vessels sailed from the ports of Sicily to the United Kingdom; but in the first fifteen months after the monopoly the number was only 157. . . . . At length the British government took very decided steps to put an end to a monopoly established in the face of commercial treaties: the coasts of Sicily and Naples were blockaded by our ships of war, and the Sicilian government, no longer daring to uphold the monopoly, accepted the mediation of the King of the French in adjusting the dispute with the British government." After this, the trade resumed its former channel.

In one of the buildings at the Works is an extensive range of upright furnaces, adapted for the extraction of sulphur from iron pyrites, in case such occurrences as these should again interfere with the sulphur-trade. Into these furnaces is placed the pyrites, a mineral containing rather more than half its weight of sulphur, and rather less than half iron; and by a careful series of processes, a large per centage of the sulphur is obtained in a form fit for the manufacturer of sulphuric acid. But at the present time the price of Sicilian sulphur is sufficiently low to render the adoption of the English mineral unnecessary. This is one of the points to which we referred in illustration of the intimate connection between commercial legislation and chemical manufacture.

The Sicilian sulphur is brought over to this country 'in bulk,' that is, stowed away in the hold of the ship. It is prepared at the Sicilian sulphur-works in masses weighing about half a ton each; and these masses generally become broken into small rubble or fragments by the time they reach the English chemical-works. So enormously has the use of this commodity increased in England, that whereas five thousand tons were used in 1820, ten times that quantity is now used annually; and we import, in fact, more than half of all the sulphur produced in Sicily.

Beginning from the heap of sulphur lying in one of the warehouses at the Works, we have to follow it through its subsequent stages. In a furnace-room are numerous furnaces for burning the sulphur, arranged on each side of a hollow wall, through which the gaseous products ascend into large vessels. Every one knows that sulphur will kindle very readily, and it is equally well known that a very suffocating gas accompanies the blue flame resulting from the ignition. This gas is sulphurous acid, and the object of the manufacturer is to collect it carefully. The furnaces are a kind of flat quadrangular chest, measuring about seven feet by five; they are made of iron, and are capable of being closed in perfectly or nearly air-tight. There is a door in the front of each furnace, through which is introduced about a hundred pounds of sulphur at a time; the sulphur is kindled, the door is closed (leaving a narrow aperture for the entrance of the air required to support the combustion), and in about two or three hours the whole of the sulphur, except a very small residue or ash, is converted into sulphurous acid vapour, which ascends the hollow wall to fitting receptacles. If one of the doors be opened, we can see the lambent blue flame from the burning sulphur, and become sensible of the well-known odour resulting from the combustion.

The sulphurous acid gas passes from these burners or furnaces into vessels so vast that it is difficult to estimate them by a common standard. Brewers' vats, 'Heidelberg tuns,' all sink into insignificance when compared with these vessels. There are two of them, each nearly two hundred feet in length, twenty in width, and twenty in height; and four others about half this length. They are not sunken tanks or cisterns, but vessels erected on the ground, formed of sheet-lead, and held together by appropriate framework. There are avenues between the vessels, or 'chambers,' as they are called; and nothing less than a walk from one end to the other of one of these avenues (such as is slightly sketched in the adjoining cut) can convey an adequate idea of the dimensions.



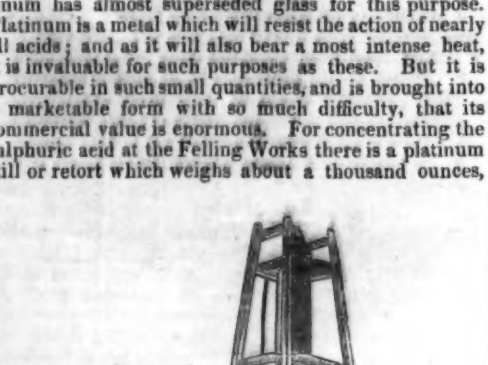
[Sulphuric-acid Chambers.]

Into these chambers the gas passes; but not alone: there are some beautiful chemical changes involved before the gaseous sulphur*ous* acid can be converted into liquid sulphur*ic* acid. The latter contains a little more oxygen than the former, for the same amount of sulphur; and a curious agency is employed for the supply of this additional portion. Into the sulphur-furnace is introduced a little nitrate of soda, placed in a dish on a stand above the burning sulphur: the heat from the sulphur occasions the evolution of nitrous acid vapour from the contents of this dish; and this vapour enters the leaden chambers in company with the sulphurous acid vapour. The two gases will not exert any particular effect on each other while in this condition; but if moisture be present, an action immediately commences. There is a steam-boiler arranged near the chambers, from which a supply of steam is obtained; and this steam, flowing into the chambers with the two gases, effects a transference of oxygen from the one to the other. The sulphur*ous* acid only requires a little further supply of oxygen to transform it into sulphur*ic* acid; and this supply it obtains from the atmospheric air (which enters with it for the purpose) by the agency of the nitrous acid gas and the steam. Sulphuric acid is not a gas; it combines with the water of the steam, and accumulates at the bottom of the leaden chambers, from whence it is drawn off at stated intervals.

The chemical niceties involved in many parts of this process are very great; but into these we need not enter. Suffice it to say that from tasteless sulphur,

from the salubrious oxygen which we breathe, and from common steam, are produced the hot and burning sulphuric acid, or oil of vitriol, in the form of a very dense liquid. This liquid falls into tanks, from whence it is pumped or forced up into other vessels, to be either sold in that state, or to be concentrated to a greater degree of strength. Such is the corroding nature of this acid, that few metals are found capable of resisting it; and on that account lead is extensively employed in the manufacture, this being one of the exceptions. For instance, the fumes pass through a leaden pipe two feet in diameter; the chambers are of sheet-lead; and the liquid acid falls into a leaden tank.

Few things are more remarkable in the manufacture than the enormous expense which this corroding tendency has entailed on manufacturers of this acid. In order to give a higher degree of concentration to the acid, it is distilled by the agency of heat; but lead will not bear this heat, and other common metals will not bear the action of the acid. Under these circumstances the stills are made either of glass or of platinum. When glass stills are used, they are heated by means of hot sand, into a bed of which they are placed; but breakages so frequently occur, that the use of platinum has almost superseded glass for this purpose. Platinum is a metal which will resist the action of nearly all acids; and as it will also bear a most intense heat, it is invaluable for such purposes as these. But it is procurable in such small quantities, and is brought into a marketable form with so much difficulty, that its commercial value is enormous. For concentrating the sulphuric acid at the Felling Works there is a platinum still or retort which weighs about a thousand ounces,



[Platinum Still, for concentrating Sulphuric acid.]

and cost nearly as many guineas, the value of the metal being about four times as much as that of pure silver! As the costly metal is made no thicker than is absolutely necessary, the portion of it exposed to the fire is protected by an iron casing.

It does not form part of our object here to describe manufactures in metal; but a few words may be introduced explanatory of the reasons why the production of platinum vessels is a difficult and tedious process. As the metal cannot be procured naturally in large masses, and as the heat of furnaces will not melt it, it is brought into workable form in an extraordinary manner, first developed by Dr. Wollaston. It is found in the metallic state, in small grains, mingled with grains of many other metals. The other metals are removed from it by chemical means, and the platinum is then presented in the form of small grains. These grains are crushed in a wooden mortar with a wooden pestle, to the state of powder, which powder is brought to a pasty form with water. The paste is put into a small ingot-mould, and pressed very powerfully by an appropriate machine, by which it is compacted into a solid form, the grains of powder cohering by a sort of welding property. This ingot is placed upon a charcoal fire, to drive away the remaining moisture; it is next exposed to the fiercest heat which furnaces can give, to remove every other extraneous substance from it; it is next hammered in particular directions, to give it a temper and toughness; and is then in the form of a small solid piece, fit to be rolled and forged into sheets, or any other practicable form. All this labour, bestowed upon a small bar only six or seven inches long, necessarily makes the manufactured article very costly.

After the acid has been concentrated to a density not much less than double that of water, it is cooled, and finally packed in large glass carboys enclosed in osier baskets.

As there do not appear, in common life, to be very many uses for sulphuric acid on a large scale, it may seem strange why such vast quantities should be made; since a large portion of all the sulphur imported is used in making this acid, and the acid produced is nearly three times as great in weight as the sulphur employed. But it is as an agent in producing many other important chemical substances that this acid is so largely used; and to some of these we will next direct our attention.

Soda, a substance so largely employed in glass-making, in soap-making, in bleaching, in washing, and in many other operations, is at the present day produced by the application of sulphuric acid to common salt; and the manufacture is one of those carried on at the Felling Works. Most remarkable have been the changes in the mode of producing this useful alkali. Some years ago the duty on salt (now employed in the manufacture) was almost unprecedentedly high: it amounted to 30*l.* per ton; whereas the commodity can at the present day be purchased for ten or twelve shillings per ton, that is, the duty was once fifty or sixty times as great as the article itself can now be actually bought for! Under these circumstances, the production of soda from this substance was not thought of commercially. At that time the soda was prepared from *kelp*, a kind of sea-weed found on the shores of the Scottish Highlands and Islands; the kelp was dried and burned, and from the resulting ash was obtained a very small per centage of soda. *Barilla*, obtained from the ash of an Italian sea-weed, was also employed for the same purpose. But common rock salt has now nearly superseded the latter, and wholly so the former. Indeed so marked has been the change, that though the commercial and manufacturing advantages have been immense, the result has been in some respects painful, since the Highlanders who used to be employed in the kelp manufacture are now wholly deprived of that source of income.

Common salt is chemically designated chloride of sodium; common soda is chemically carbonate of soda; and the process of manufacture consists in separating the sodium from the chlorine, and making it the chief

element in a new compound: and it instructively illustrates the way in which one chemical process necessarily involves another — that the very same operation which leads to the production of carbonate of soda from one element of the salt, leads to the production of muriatic acid from the other. So rapidly has this branch of manufacture extended, that it was estimated in 1838 that more than seventy thousand tons of carbonate of soda were made from common salt in that year.

On entering those buildings of the Works where the soda process is carried on, the peculiar odour of muriatic acid is very perceptible, very different from that diffused throughout those before visited. The rock salt is procured from the vast beds at Northwich in Cheshire. It is exposed to various processes, by which the chloride of sodium is converted into a sulphate of soda; then this into what is called ball-soda; then this into the soda-ash employed in making soap and glass; and, lastly, this into the crystallized soda of the shops. Throughout these operations a succession of chemical changes ensues, not less remarkable than those in relation to sulphuric acid.

A given weight of salt is placed in a reverberatory furnace, that is, one in which the heat is echoed or reflected down from a concave roof upon the ingredients in the furnace. The salt is placed in a leaden pan within the furnace, and sulphuric acid is let down upon it through a leaden pipe in the roof of the furnace; or rather, the decomposition is first partially effected in an iron pan heated below, and then finished in the reverberatory furnace. The salt liquefies in the acid; and the heat which is brought to bear on the mixture soon causes a gaseous vapour to ascend. This gas is muriatic acid gas, containing as one of its ingredients the chlorine which had before been in the salt. The muriatic acid thus produced has often been a source of great trouble and expense to manufacturers. It is so deleterious, that if allowed to mingle with the atmosphere near the ground it would do great mischief; and hence the giant chimneys which such works exhibit, intended to carry off the gas to a great height. The gas, however, is now converted to a liquid form by an ingenious arrangement. All the furnaces discharge their muriatic acid gas into a bulky stone tower, about forty feet high by eight feet square. This tower is filled with coke, upon which a stream of water is constantly falling from above; and the gas, ascending the tower from the flues of the furnaces, meeting with an innumerable series of little streams of water trickling through the coke, becomes absorbed by the water, and falls again in the form of liquid muriatic acid. Thus a double advantage is gained by this plan: the muriatic acid is preserved in a form which renders it available for other departments of manufacture; and the atmosphere is saved from admixture with such a deleterious ingredient.

Meanwhile the salt has greatly altered its form. When the muriatic acid, by the application of heat, and by frequent stirring, has been removed from the furnace, the pasty mass which remains is sulphate of soda; and this sulphate is, at a particular period, drawn out of the furnace in a dry state.

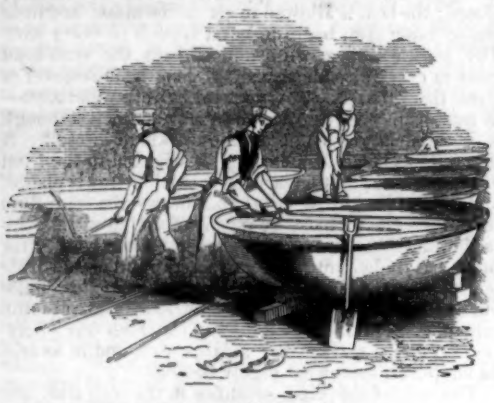
Then ensues another process, in which the chemical changes are too complex to be minutely detailed here, but whose general character may be pretty clearly explained. In one of the buildings are six furnaces in a row, upwards of twenty feet long each: these are called *balling-furnaces*, for the conversion of sulphate of soda into ball-soda. The sulphate is mixed up with chalk or lime, and with coal, both ground very fine at a mill situated in one of the buildings of the Works; and the whole are sifted to the state of powder before being put into the furnaces. When the mixed powder becomes heated, the coaly portion ignites at the surface; and when the mass begins to become liquid, a workman opens a door in the front of the furnace, introduces a rake or shovel, and turns the mass over, so as to expose a new surface uppermost. The door is again closed; the heat is allowed to act on the mass; and little jets of flame then begin to burst from it in every part. The workman next stirs and spreads the semi-fluid mass in every direction; and at length he removes it from the furnace. This is a very pretty operation— at least it may be regarded so by a by-stander, although it is rather a warm one to the workman himself. A low four-wheeled iron carriage is wheeled to the front of the furnace; on this carriage a shallow tray is placed, and into this tray the workman draws the semi-fluid mass from the furnace, by means of a kind of rake introduced at the door of the furnace. Shortly after the mass has fallen into the carriage, innumerable little jets of flame, called by the workmen 'candles,' burst out at its surface, and present a curious miniature illumination. The room or building in which this operation is carried on is rather a large one, and is, as may be supposed, somewhat highly heated.

The semi-fluid mass solidifies in the iron tray, and comes out as a square mass, measuring about three feet square by one in thickness. This is called ball-soda, or crude soda, or British barilla, and is the result of a curious series of chemical changes. The matters put into the furnace were coal, lime, and sulphate of soda; and these elements become so mingled and transferred by heat, that they appear, in the ball-soda, chiefly as carbonate of soda and sulphuret of calcium.

Next ensues the separation of the two ingredients just named: the former valuable, and indeed the object of the whole operation; the latter valueless, up to the present time. The ball-soda is put into an oval tank, and covered with water, which is allowed to act on it for a considerable time, as a means of dissolving the carbonate of soda. The liquor is drawn off at the bottom, and more applied; and so on until all the carbonate has been dissolved. The point here aimed at is to dissolve all the carbonate and none of the sulphuret, for the latter would spoil the former. When this is accomplished, the liquor containing the dissolved carbonate is placed in an evaporating furnace, where, by the application of heat at the surface of the liquid, all the watery part is caused to evaporate; and the solid which remains is chiefly carbonate of soda, with a very small admixture of sulphur. By a further exposure to the heat of a furnace, this sulphur is driven off; and there remains a yellowish earthy substance, which is the common soda-ash or soda-salt, employed extensively in various manufactures. It contains about fifty per cent. of pure soda.

One more stage of improvement occurs before the soda is finally completed. For some purposes this earthy carbonate of soda will not suffice: it must be in a crystallized form; and to effect this crystallization another series of buildings, of processes, and of vessels is necessary. The soda-ash is again dissolved in water, again allowed to settle, and then boiled to a certain degree of consistency. Next ensues the crystallization, which is one of the most striking features in the Works. In a very large and cool building are upwards of a hundred hemispherical cast-iron vessels, from five to ten feet in diameter. In these the liquor is placed, after having deposited its solid impurities; and here it remains until all that will crystallize has done so. It is a beautiful sight to see the large crystals radiating from the sides of the vessels towards the centre, and absorbing, as it were, into their substance more and more of the liquor, until only a little of this latter remains. After several days, the crystals are broken out from the vessels, to be packed in barrels for the market; while the remaining liquid, called the 'mother-liquor,'

by a further process of evaporation yields a very coarse kind of soda, fitted for some manufacturing purposes, —thus adding one more to the forms in which soda is presented by this interesting chain of processes.



[Soda-crystallizing Pans.]

One thing has yet to be noticed. What becomes of the solid impurities which occur in the process? This is one of the difficulties to which a chemical manufacturer is exposed. The sulphuret of calcium, the solid and useless ingredient in the ball-soda, is a veritable source of trouble and expense. No profitable mode of applying it has yet been introduced: it cannot be melted and washed away, or heated and burned away; nor must it be thrown into the river. The result is exhibited by what has taken place at the Felling Works. Here, between the Works and the river, an enormous heap of 'waste' has accumulated, covering an area five or six acres in extent, and mounting to a height of thirty or forty feet. Day by day is this heap increasing in extent; and we believe that more land has lately had to be purchased, to form a resting-place for heaps yet to accumulate. The earthen waste is not thrown here heedlessly: it is laid in a compact form, having a smooth and level surface at the top; and if the memory of present things were to pass away, future geologists might be puzzled to conjecture how such a mound got there. Not only the sulphuret of calcium from the soda process, but silica and ashes from other processes help to swell this heap.

Another process carried on in these Works, and to which we may next direct our attention, is the manufacture of *chlorine* and of *bleaching-powder*; those two wonderful agents which have wrought such improvements in bleaching. Bleaching-powder is chemically called chloride of lime; but its most marked property has given it the former distinctive name.

Here we have another example of the influence which legislative matters exert upon chemical manufactures. If the duty had not been taken off common salt, it may be safely averred that the manufacture of these articles would not have reached its present height. Salt not only yields soda from one of its constituents, and muriatic acid from the other, but this acid itself is made to yield chlorine, by separating hydrogen from it. Chlorine is a gas, and as such is not in a convenient form for sale and commercial transit; but by causing it to be absorbed by any dry and cheap substance, such as lime, it can be brought into a convenient form. Such is the case in practice. Chloride of lime is now used to an immense extent in different branches of manufacture, the lime being merely a vehicle for containing the chlorine, and all the remarkable chemical effect being due to the latter.

Chlorine requires for its production or evolution a degree of care in the choice of vessels, analogous to that exhibited in so many other branches of chemical manufacture. In one of the buildings at the Works are a series of vessels made of stone contained within-side iron vessels; and into the innermost vessels are put the necessary ingredients. These are muriatic acid and oxide of manganese. Steam is admitted between the inner and outer vessels, by which the mixture is raised to the required temperature; and by the mutual action of the chemical ingredients they become so altered in their combinations as to produce muriate of manganese, water, and chlorine gas, the last named of which is the object of the manufacture. In this process, and in the subsequent one of causing the chlorine to be absorbed by lime, the most scrupulous precautions are taken to prevent the escape of any of the gas into the open air; since it is so deadly a poison, that the inhalation of a very small portion of it would suffice to take away life. Some years ago, when the muriatic acid gas was allowed to go to waste up the chimneys of sulphuric acid works, chlorine was produced from sulphuric acid, salt, and the oxide of manganese; but the muriatic acid is now economically used instead of the sulphuric acid and the salt—thus at once cheapening the product and saving the atmosphere from contamination.

The mode of impregnating lime with the gas is very curious. A chamber is fitted up in the most completely air-tight manner, with a few openings carefully secured. On shelves in this chamber is deposited slaked lime in powder, spread out so as to allow the chlorine to act upon it. The gas, as it escapes from the vessels, flows through a pipe into this chamber, which it gradually fills; and as soon as it comes in contact with the lime, the two substances unite, forming chloride of lime, by which the whole of the gaseous element is absorbed.

This powerful agent is in a most convenient form for manufactures. When the chloride of lime is immersed in water, it dissolves, and the water becomes impregnated with the chlorine, which then forms the bleaching-liquid now so largely used in the manufacturing districts. About a century ago our manufacturers of linen used to send their cloths to Holland to be bleached, where they were steeped in potash ley, then washed, then steeped in buttermilk, and then laid out on the grass for several months; so that the linen was thus out of the maker's hands for seven or eight months before he could bring it into the market. A process very similar next became established in this country; the goods being still several months under process of bleaching, but the transference to and from Holland being no longer necessary. Next sprang up an improvement by the substitution of sulphuric acid for milk, whereby the same effect was wrought in one day which before occupied six weeks, and brought the whole bleaching process within a period of three or four months. Next ensued the discovery that a particular gas, evolved by the action of manganese on muriatic acid, had the power of destroying vegetable colours, or of bleaching; and about sixty years ago, Bertholet practically applied this new gas (chlorine) in bleaching. Next followed the introduction of this method into England and Scotland, and the institution of experiments for facilitating the use of the gas in bleaching establishments. If used as a gas, the effects were highly deleterious to the workmen; if absorbed by water, the water gave out a very offensive odour. Potash was added to the chlorine water, to remove the smell; next, the cloth was passed through lime-water previously to the application of the chlorine; and next, Mr. Tennant, of Glasgow, contrived the means of making a liquid chloride of lime, which was the open-

ing to a field of vast importance. One more step was the devising a mode of producing a *dry* chloride of lime which should be capable of being easily packed in barrels, which should retain all the bleaching properties of the chlorine without its offensive odour, and which should be procurable at a cheap rate. This has been done; and the chloride of lime of modern times is presented to us as one of the most successful instances of chemical science applied to manufactures. Instead of eight months, a period of a few hours only is now necessary for the process of bleaching. Dr. Thomson states, "A bleacher in Lancashire received fourteen hundred pieces of grey muslin on a Tuesday, which on the Thursday immediately following were returned bleached to the manufacturer, at the distance of sixteen miles, and they were packed up and sent off on that very day to a foreign market. The quick return of capital which is thus made is a benefit entirely to be ascribed to the new mode of bleaching." The mode of bleaching with this invaluable agent has been described in the Supplement for July, 1843.

We have yet to glance through that department of the Felling Chemical-Works which is appropriated to the production of artificial alum, a process scarcely less beautiful in a chemical point of view than those which have already engaged our attention.

In a notice of the alum-works at Hurlet, in Scotland, at p. 421 of last year's volume, we explained that the common alum is there produced from an ore found in exhausted coal-pits: an ore containing sulphur and alumina, two of the constituents of alum. It was also intimated that a mode is sometimes adopted of making alum artificially, without having recourse to any kind of alum-ore or alum-stone. Now it is this latter mode of proceeding which is followed at Felling. Crystallized alum is called chemically a 'sulphate of alumina and potash;' being composed of sulphuric acid, alumina or pure clay, and potash; and provided those three agents can be properly brought together in proper proportions, they will still form alum, whether derived from decomposed ore or from the mixture of the different agents.

The buildings appropriated to the alum manufacture have their own vessels and their own peculiar arrangements, some of them very interesting. The alumina is procured from Cornish clay, a fine, smooth, and white clay, which is extensively employed in the manufacture of porcelain and the finer kinds of pottery. This clay is brought from Cornwall in balls or blocks, as dug out of the earth, and is ground under a heavy stone to a state of great fineness. The powdered clay is next calcined in an appropriate oven, to drive off the moisture and vegetable matter which may be combined with it. The calcined clay is next placed in an oval tank sunk in the ground; and to this is added the second ingredient necessary to form alum—that is, sulphuric acid. The acid has such a powerful action on the clay, that the two together soon form a boiling mixture, although no heat whatever is applied to it; the instance being one of those in which rapid chemical combination gives rise to the evolution of heat.

When these two agents have combined, they are mixed with a considerable quantity of water, and allowed to settle, by which those solid parts of the clay which resist the action of the acid are allowed to fall to the bottom of the vessel. The liquid (which is a solution of sulphate of alumina) is then pumped up into leaden vessels, where it receives the addition of some sulphate of potash, as a means of giving the third ingredient necessary to the formation of crystallized alum. The different ingredients are allowed to remain quiet in a circular sunk vessel, where the alum gradually crystallizes round the sides, shooting forth large crystals towards the centre, where the mother-liquor (or portion which will not crystallize) remains.

But the alum thus produced is not pure and fine in quality. It undergoes the process of *roaching*, to bring it to a better condition. This roaching (or roching, as it may perhaps more properly be spelled) is probably meant to imply the production of an alum similar to roch-alum; and this latter derived its name from Roccha in Syria, where it was first made. In the process of roching, steam is allowed to act upon the alum, so as to dissolve it, and to make with it a very strong solution. This is done in a leaden vessel; and from this vessel the solution is transferred to large cylindrical crystallizing vessels, where it attains the final state in which it is sent to market.

When the crystallization is complete, the cylindrical vessels present a very beautiful exemplification of this kind of chemical action. They are about seven feet

[Cylindrical Mass of Crystallized Alum.]

high by five in diameter; and upon looking in at the top of any one of them, we see a thick hollow cylinder of crystallized alum, with a portion of floating water in the centre: the mass appears like an irregular rock-work of sparkling transparent crystals, many of them of large dimensions, and all with the most perfect symmetry of form, presenting the keen apex, the fine, clear, straight edges, and the regular and even faces of the 'octohedron,' the geometrical form which these crystals assume. The manner, too, in which the alum is extracted from the vessels is calculated to show the beauty of the crystallization. The vessels are capable of being taken to pieces as they stand, by the removal of certain hoops and staves; and the alum is then exhibited to the eye as if it were one magnificent cylindrical crystal, as large as the interior of the vessel had been. The liquor is removed from the inside, and the alum, being broken up into convenient fragments, is packed in barrels for the market.

There is one peculiarity about alum which has led to an entirely new branch of manufacture, now being carried on extensively at the Felling Works. We have said that it is a sulphate of alumina and potash. But it is not necessarily so: in some instances soda, in others ammonia, has been used instead of potash.

The truth is, that these ingredients are used chiefly as agents to induce the crystallization of the alum. Sulphate of alumina will not crystallize; the sulphuric acid and the alumina have combined, and the resulting compound possesses most of the useful properties of alum; but it cannot, by itself, be brought into a crystalline form. When, however, any one of the three above-mentioned alkalis is added, the sulphate acquires this power, and becomes a crystallized sulphate of alumina and potash. On the other hand, this potash is of no practical service in the chief purposes to which alum is applied in the arts: the sulphate of alumina is the real working agent; and if this could be obtained in a pure state and in a solid form, the potash would in most cases be unnecessary. It happens that the iron contained in small quantity in the clay, and which would injure the alum if allowed to form one of its constituents, is with difficulty removed except by some mode of crystallizing the alum; and it is not until recently that the difficulty has been practically removed. There is a 'patent alum' now made (the patent for which is, we believe, in the hands of the proprietors of the Felling Works), the chief characteristic of which is, that it possesses the efficient properties of alum, but without containing potash.

In making this alum, sulphuric acid and Cornish clay are used, as in the other case; but the clay is used in greater proportion, so as to form a kind of mortar or thick paste. This mortar is placed in a heated trough, where the moisture is so far evaporated as to convert the mass to the form of a dry earth. From the trough it is removed to tanks, where water is employed to dissolve it; and while in the liquid state the composition is acted upon by an agent intended to remove the iron: this being the only contained ingredient which is injurious to the alum. The agent employed attracts or combines with the iron existing in the clay, forming with it the coloured pigment known as Prussian blue. This Prussian blue is allowed to subside, and the remaining liquor, being a solution of sulphate of alumina, is boiled till all the water is driven off. The solid residue is formed into cakes an inch or two in thickness, and in this form it comes into the market. Instead of being a crystal, it is an opaque earthy solid, differing from common alum in the circumstance of containing no potash, but possessing in common with it the qualities which render it valuable in the arts.

The Prussian blue is procured in far too large quantity to be allowed to remain in that state: it is restored again, by chemical means, to the form which it before presented, ready to be again used in making more alum. This principle is exhibited in many departments of a chemical work: where a chemical substance, after being modified in its character by the aid it has afforded in making other substances, is restored to its original form, and thereby fitted to render similar aid in other instances.

We have now noticed the chief manufacturing processes carried on at the Works under consideration. They involve, as may readily be supposed, a very extensive variety and arrangement of buildings, subsidiary to the actual operations carried on. For instance, there are five steam-engines in different parts of the Works, for pumping up water, pumping liquids from one vessel to another, setting in motion the mills and stones for grinding clay and lime, and other operations requiring great motive power. There are carpenters' shops, smiths' shops, coopers' shops, plumbers' shops, and others of a similar kind for keeping in working order the various vessels employed in the Works; the lead vessels and pipes, especially, are so numerous, that there is constant work for plumbers in one way or other. There is also an important department which we may perhaps term the very grammar of the whole, viz. the *laboratory*, the spot wherein are determined the numerous points connected with the chemical science of the manufactures. This laboratory contains all the appliances for such a purpose—air-furnaces, reverberatory furnaces, sand-baths, stills, retorts, and the varied apparatus for experimental trials on the mutual action of chemical agents. A chemical library, too, is a necessary appendage to such a place.

When, leaving the actual buildings themselves, we go out upon the spoil-bank or mound of rubbish, we there get a bird's-eye view of the arrangements whereby the Works are connected with the river Tyne. Railways traverse the ground in all directions, affording easy means of communication. In the first place the coarse materials, such as sulphur, salt, lime, coal, &c. are landed at a wharf on the south bank of the river; and are thence hauled up an inclined railway, through a tunnel, to the Works, by means of steam-power; and when arrived there, other railways convey these materials to the various buildings wherein they are to be brought to bear upon the manufactures. Then, when the manufactured goods are finished, the same system of railways furnishes a medium for conveying them down to the river, there to be shipped off to various quarters. Among all the busy rivers of England, the Tyne is in this way one of the busiest. At short intervals along both of its banks, for a distance of many miles, there are similar outlets for the various manufactures produced. The Chemical Works, the Glass Works, the Potteries, and above all the Collieries, all have their wharf or their 'staith,' their railways or their inclines, for connecting the Works above with the river below. The Chemical Works, too, have their clusters of chimneys, their spoil-banks of waste, and their labyrinth of buildings, to add to the features of the scene.

Such are Chemical Works. Some manufacturers make one kind of acid or of alkali, some another; one firm may have a reputation for a particular kind of salt or chemical agent, another for another; and, to understand the minute details, it would be necessary to follow the manufacturing routine of all the substances one by one. But the broad principles are the same in all. There is in all of these Works the same exhibition of lofty chimneys, large and variously arranged buildings, furnaces and ovens in almost endless variety, boilers, heaters, coolers, stills, crystallizing vessels, cisterns, tanks, pans, and a multiplicity of other apparatus; while they all likewise agree more or less in this—that there is no lack of odours from some of the chemicals under process of manufacture. It is perhaps scarcely necessary to remark, that the shops of the chemists and druggists are supplied with drugs of these various kinds from the Chemical Works, through the agency of wholesale dealers. There are in London several wholesale druggists who accumulate in their warehouses the crude drugs from every part of the world, not only from the chemical manufacturers, but from foreign merchants and dealers; and these drugs, passing into the hands of the retailers, are by them sold in smaller quantities, or are made up into the various well-known pharmaceutical preparations.

We must, in conclusion, acknowledge the courteous liberality of the proprietors in affording facilities for preparing this sketch; and this is the more due, because Chemical Works are not, in general, so readily opened to strangers as those in which Metallurgic or Textile manufactures are carried on.